Soils and Geology Sensitivity Mapping in Western Canada

Report of June 27, 28 Meeting,
Victoria, B.C.

Prepared by:

Coordinating Committee on Soils and Geology Sensitivity Mapping

Prepared for:

Western and Northern Canada LRTAP Technical Committee

July 1983

ACID RAIN
PLUIES ACIDES

BC Ministry of Environment

Alberta ENVIRONMENT

Saskatchewan Environment

Manitoba Environment and Workplace Safety and Health

Northwest Territories Renewable Resources

Canada

SOILS AND GEOLOGY SENSITIVITY MAPPING

IN WESTERN CANADA

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On Behalf of the
Coordinating Committee on
Soil and Geology Sensitivity Mapping

For:

Western and Northern Canada LRTAP
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TABLE OF CONTENTS

	Page
1. INTRODUCTION	1
2. BACKGROUND	2
3. MANDATE AND OBJECTIVES	4
4. SOILS AND GEOLOGY SENSITIVITY MAPPING IN EASTERN CANADA	5
5. ISSUES AND AGREEMENTS	7
5.1 Definition of Sensitivity	7
5.2 Target Ecosystems and Processes - Western Canada Mapping	9
5.3 Compatibility of Mapping Between Provinces and with Eastern Canada	11
5.4 Mapping Scales	13
5.5 Classification Criteria, Class Limits and Assessment Procedures	15
5.6 Mapping Methods	25
5.7 Organic Soils	27
5.8 Barren Areas	28
5.9 Acid Loading Limits	29

TABLE OF CONTENTS (Continued)

Page

6. CONCLUDING COMMENTS..... 31
6.1 TIMING..... 31
6.2 ALTERATIONS TO CONCLUSIONS IN THIS REPORT..... 31
6.3 REVIEW OF DRAFT MAP LEGENDS, MAPS, REPORTS..... 31

REFERENCES 33

APPENDIX I 35

1. INTRODUCTION

Representatives from Manitoba, Saskatchewan, Alberta, British Columbia, Environment Canada and the Department of Indian Affairs and Northern Development met in Victoria, B.C. on June 27 and 28, 1983. Meetings were held to allow representatives:

1. To become fully informed of the rationale, methods and criteria used in Eastern Canada soils and geology acid precipitation sensitivity mapping.
2. To reach agreement on methods and criteria to be used for acid precipitation sensitivity mapping in Western Canada.

The primary purpose of this document is to report on discussions and agreements relating to item 2 above. A number of separate issues will be covered. A short background is presented to give perspective to the discussions and agreements. Only a very limited discussion will be presented of rationale, methods and criteria used in Eastern Canada. This information is available in various published reports. However, the discussions and agreements reached do reflect the Eastern Canada experiences. Methods and criteria used there have been accepted or adopted in the case of a number of issues.

The data base available in each of the provinces, the Yukon and the Northwest Territories was reviewed at the meeting, preparatory to discussion of issues such as scale of mapping, complex map units, barren areas and properties of soils/geology to be used as criteria for sensitivity classification. This review will not be discussed in this report but recommendations and conclusions do take account of the nature and content of the data available.

2. BACKGROUND

Two previous reports on behalf of the Coordinating Committee on Soils and Geology Sensitivity Mapping have been prepared for the Western Canada Long Range Transport of Air Pollutants (LRTAP) Committee (Wotton, 1981; Wiens, 1982). Also prepared, was a proposal by the Lands Directorate, Enviroment Canada, for coordinated federal-provincial terrestrial sensitivity mapping in Western Canada (Rubec, 1982). The first report reviewed the status of sensitivity mapping and related studies in Western Canada. The second report outlined general agreements and outstanding issues relative to proceeding with coordinated, compatible sensitivity mapping in Western Canada. It also reviewed responses of Western Canada representatives to the proposal by the Lands Directorate.

Policy decisions by the Western Canada LRTAP Consultative Committee as well as the Technical Committee in Winnipeg on December 13, 1982 confirmed that each western province should be responsible for their own sensitivity mapping. However, coordination by the in place coordinating committee should continue and Enviroment Canada (Lands Directorate), Agriculture Canada (Land Resource Research Institute) and Energy, Mines and Resources (Geologic Survey) should participate in the coordination and in an advisory capacity.

The need for a face-to-face meeting of representatives on the Soils and Geology sub-committee was again recognized at the Western Canada LRTAP Technical Committee meeting on March 15, 1983. Compatibility of products with Eastern Canada would require explanation by Lands Directorate of what was actually done there. Certain issues of sensitivity classification criteria and mapping methodology would have to be more fully discussed before agreements could be reached. Strong support for such a meeting was given. Ultimately arrangements were concluded and the meeting was held in Victoria, B.C. on June 27 and 28. Attending the meeting were the following:

D. Cowell	- Lands Directorate, Environment Canada (Burlington)
D. Graveland	- Earth Sciences Division, Alberta Environment
H. Luttmerding	- Terrestrial Studies, British Columbia Environment
W. Pagham	- Northern Affairs Program, Department of Indian Affairs and Northern Development(NWT)
G. Padbury	- Saskatchewan Institute of Pedology
J. Senyk	- Lands Directorate, Environment Canada (Victoria-rep. for Yukon area)
D. Wotton	- Manitoba Environment, Environment Standards and Studies
J. Wiens (Chairman)	- Terrrestrial Studies, British Columbia Environment

3. MANDATE AND OBJECTIVES

The mandate of the Soils ad Geology Sensitivity Mapping Coordinating Committee and objectives of the meeting were highlighted at the outset of the meeting by Dr. R.G. Wilson, Air Management Programme Manager, B.C. Environment and current Chairman, Western Canada LRTAP Technical Committee. The mandate of the sub-committee simply stated, was to review all issues related to acid sensitivity classification and mapping in Western Canada to allow preparation of a report which would define sensitivity classification criteria, classes, and mapping methods to be used by all jurisdictions in Western Canada. The maps should be consistent and compatible between provinces and as compatible as possible with those prepared for Eastern Canada.

4. SOILS AND GEOLOGY SENSITIVITY MAPPING IN EASTERN CANADA

A number of agencies including Agriculture Canada (AC), the Geologic Survey of Canada (GSC), and Lands Directorate of Environment Canada have prepared maps of terrestrial sensitivity to acid precipitation. Agriculture Canada's efforts have been directed primarily to soils of areas in agricultural use or to impacts on agricultural production (Wang and Coote, 1981; Coote, Siminovitch, Shah Singh and Wang, 1981; Coote, Dumanski and Ramsey, 1981). The efforts of the Geologic Survey have emphasized rating and mapping sensitivity of bedrock to acid precipitation, or sensitivity of bedrock as modified by surficial deposits (Shilts, 1981). Lands Directorate, Environment Canada through its activities and responsibilities as part of the Impact Assessment Work Group (Work Group I) and in fulfillment of the requirements of the Memorandum of Intent (MOI) on Transboundary Air Pollution has drawn on the work of AC and GSC. It has produced broader coverage maps. It has also attempted to deal with impacts on a wider range of ecosystem components (Cowell, Lucas and Rubec, 1980; Lucas and Cowell, 1982; Bangay and Riordan, 1983).

The Lands Directorate sensitivity mapping process has evolved with time and experience. It has also been subject to influences from technical discussions of methodology between Canada and the U.S. and to influences from joint Canada/U.S. Coordinating Committees. Early emphasis was on development of an approach to terrestrial ecosystem sensitivity assessment which considered numerous ecosystem components simultaneously or in an integrated holistic manner (Cowell, Lucas and Rubec, 1980; Rubec, 1982;). Ecodistricts served as land areas which were rated as to sensitivity. More recently, land areas delineated according to characteristics of soils and bedrock geology per se have served as the basic units to be rated. Soils and geology have thus emerged as the factors to be rated as to their sensitivity.

Terminology has also changed with time. Earlier maps and criteria tables referred to:

- Forest Productivity Sensitivity to Acid Precipitation
- Aquatic Input Sensitivity to Acid Precipitation
- Bedrock Sensitivity to Acid Precipitation
- Soil Sensitivity to Acid Precipitation

Final MOI reports, present maps depicting:

- The Potential of Soils and Bedrock to Reduce the Acidity of Atmospheric Deposition in Eastern North America
- Terrain Characteristics of Eastern Canada

With respect to terrestrial impact sensitivity interpretation and maps labelled "Terrain Characteristics.." the statement is made:

> "For this report mapping is concentrated on terrain characteristics, especially soil chemistry (or its surrogate), of eastern North America rather than sensitivity per se. It is hoped these maps will provide a useful basis for comparison and for eventual interpretations of terrestrial sensitivities once actual impacts are documented."

The change in terminology has been concurrent with and perhaps a result of at least two things:

1. The recognition that aquatic systems are particularly sensitive ecosystem components and the potential of soils and bedrock of watersheds to reduce acidity is an extremely important and a priority interpretation.
2. Acidic precipitation affects various physical, chemical and biological processes in soils and geology (e.g. Al solubilization, base cation leaching) to different degrees. The degree of change in each process affects the sensitivity of the area differently for various forest or agricultural crop species, for example. Only when these process changes and impacts are understood will a reliable sensitivity rating be possible.

5. ISSUES AND AGREEMENTS

This section contains the substance of the report. It will outline pertinent points of discussion and itemize conclusions reached on various aspects of the issues. This section follows a consistent format with statements of discussion first, followed by conclusions. These conclusions can be taken as recommendations to guide sensitivity rating and mapping in the provinces and therefore may be used in preparing terms-of-reference for work to be performed.

5.1 DEFINITION OF SENSITIVITY

5.1.1 DISCUSSION

Numerous definitions of sensitivity of terrestrial ecosystems have been proposed. Most commonly one or more terrestrial components are targeted for sensitivity mapping and rating. Thus ratings have been made for soils, bedrock geology, forest productivity etc. It was recognized by the group that objectives in preparation and use of a sensitivity map will vary. A single sensitivity map is unlikely to serve all purposes even if it were possible to prepare. Therefore it was recognized that a target component(s) must first be identified if a meaningful sensitivity map is to be made.

Recognizing acidification of the aquatic ecosystem to be of particular concern, terrestrial sensitivity mapping in Eastern Canada has emphasized the potential of soils and geology to reduce precipitation acidity prior to its entry into the aquatic regime. This objective has necessitated rating criteria different than those often used (e.g. to rate soils and bedrock geology as they affect productivity of forests or agricultural crops, or changes in physical, chemical or biological soil properties). Soil and geology sensitivity was thus defined not primarily as the ability of soils to resist changes in their own pH, nor according to their expected loss of exchangeable bases, soluble aluminum or sulphate. Such criteria have been used to define soil sensitivity in the literature.

Cause effect linkages between acidic precipitation and impacts on forest or agricultural systems were considered to be poorly understood as yet. Terrestrial mapping in Eastern Canada therefore focussed on mapping terrain characteristics though attempts at forest productivity sensitivity ratings were made.

Soils and geology sensitivity mapping in Western Canada to date has tended to be based on a definition of sensitivity which emphasizes the capacity of soils to resist change in pH (buffering capacity) and base saturation (Shewchuk et. al. 1981; Holowaychuk and Lindsay, 1982; Quesnel and Wiens, 1983). However, consideration has also been given to quality of leaching waters (Shewchuk et. al, 1981). This is understood to be based on the belief that trends in relationships do exist (e.g. a poorly buffered soil has less capacity to reduce impacts of acid precipitation on aquatic systems).

Dave Graveland, representative from Alberta, proposed the following definition:

> "Sensitivity is an expression of the respective susceptibilities of different soils to changes in one or more of the following: pH, base saturation percentage and solubilization of aluminum in response to a given input of acidity."

5.1.2 CONCLUSIONS

1. A clear understanding of intended map use and definition of sensitivity is integral to classification criteria and class limits.

2. Several potential uses of sensitivity maps in Western Canada should be accommodated by the chosen definition for sensitivity. One should be the rating of potential of soils and geology to reduce acidity of precipitatin before its entry into water. Others should be the sensitivity to impacts on vegetation including forest and agricultural species.

3. It appears a single definition of sensitivity of soil and geology is not possible unless it is expanded to incorporate all objectives for sensitivity rating.

4. It appears that a definition for sensitivity of soils and geology should be written for each specific objective of rating. In any case, development of classification criteria is the substantive activity critical to each of these objectives.

5.2 TARGET ECOSYSTEMS AND PROCESSES - WESTERN CANADA MAPPING

5.2.1 DISCUSSION

1. It has been the intention for soils and geology sensitivity mapping in Western Canada to reflect terrestrial sensitivity. Assessment and mapping of aquatic sensitivity is being carried out separately and independently using such water chemistry parameters as alkalinity, calcium saturation index etc.

2. From the final MOI report and the presentation by Daryl Cowell it is apparent that soils and geology mapping in Eastern Canada has been directed primarily at assessing aquatic sensitivity. This is based on the premise that soils and bedrock geology information provides the best indication of the long term capacity of watersheds to buffer acidic deposition.

3. It is contended in the final MOI report that terrestrial impacts of acidic deposition (e.g. on forest and agricultural systems) are not well understood and therefore sensitivity mapping is difficult. Mapping has thus concentrated on terrain characteristics rather than sensitivity per se in the hope that the maps will provide a useful basis for eventual interpretations of terrestrial sensitivities once actual impacts are documented.

4. Some attempts at interpretations and mapping of sensitivities of forest systems have been made by Lands Directorate for E. Canada. This has been done by rating sensitivities of mapping units to soil processes (e.g. base cation loss, soil acidification and Al solubilization) and making certain assumptions regarding significance of impacts of these processes to forest productivity.

5. Agriculture Canada has classified and mapped agricultural land in Eastern Canada according to its sensitivity to acid precipitation (Wang and Coote, 1981; Coote et. al., 1981). The criterion used to rate sensitivity was the exchangeable base content of soils. It was contended simply that the more exchangeable bases there are, the greater will be the neutralization capacity of the soil and the less will be the influence of acid precipitation on soil pH.

5.2.2 CONCLUSIONS

1. It remains a primary objective of Western Canada soils and geology sesitivity mapping to portray the potential for terrestrial impacts. This is prticularly so because of the parallel work being done on aquatic sensitivity.

2. It is recognized that acidification of aquatic systems are of particular and often primary interest. Given that soils and bedrock of watersheds can reduce acidity of acidic precipitation, soils and geology mapping in Western Canada should accommodate this interpretation if possible.

3. To meet the objective of portraying the potential for terrestrial impacts, ratings should be made of mapping units for sensitivity to the following soil chemical process: soil acidification, base cation loss, Al solubilization

5.3 COMPATIBILITY OF MAPPING BETWEEN PROVINCES AND WITH EASTERN CANADA

5.3.1 DISCUSSION

1. Compatibility of soils and geology sensitivity mapping between Western Canada provinces/territories is a stated objective of the Western Canada LRTAP Consultative and Technical Committees.

2. Compatibility is a matter of degree. Decisions must be made on what levels of compatibility are necessary and useful, and what minimum requirements should be.

3. There are several aspects to the matter of compatibility. Likely the most important is compatibility of classification criteria and class limits for sensitivity rating. Also important are compatibility of data sources, map scale, map polygon labelling and map legend format.

4. It is anticipated that the Western Canada LRTAP Technical Committee will eventually publish a single summary report combining maps and narrative for dealing with each of acidic deposition loading, aquatic sensitivity and terrestrial sensitivity. It is important that at that time products are sufficiently compatible to allow preparation of smaller scale maps, overlays etc.

5. Compatibility of mapping with work done in Eastern Canada must recognize several things:

   a) Several mapping scales and presentation scales have been used by the Lands Directorate for mapping in conjunction with MOI work.

A scale of 1:1 000 000 was used for the maps of "Potential of Soils and Bedrock to Reduce Activity of Incoming Acidic Deposition" but smaller scale presentation maps have also been published. Trial maps of Sensitivity of Forest Systems were of a smaller scale (1:5 000 000 blown up to 1:3 000 000).

b) Shilts' (1981) map of bedrock sensitivity to acid precipitation was prepared at a scale of 1:1 000 000.

c) The map of sensitivity of agricultural land in Eastern Canada by Wang and Coote (1981) was presented at a scale of 1:5 000 000.

5.3.2 CONCLUSIONS

1. Every effort must be made to achieve compatibility between provinces in soils and geology sensitivity mapping with respect to the following:

   a) Scale of map product(s)
   b) Soil and geology factors for which information will be compiled (extracted from existing maps or inferences made)
   c) Classification criteria and class limits used for rating sensitivity of soils and geology to acid precipitation (i.e. the evaluation procedure for assessing sensitivity or the potential to reduce acidity of incoming acidic precipitation)
   d) Polygon composition and labelling and general legend content.

2. Compatibility between the western provinces and the territories should be achieved for items b to d above.

3. Compatibility between the western provinces, territories and Eastern Canada mapping should be achieved for items b and c above.

4. Divergence and lack of compatibility between provinces and territories and between Western Canada and Eastern Canada will occur due to differences in data bases. This must be expected and accepted and essentially nothing can be done about it.

5. Agreements reached on matters of scale, factors to map, classification criteria and class limits, polygon labelling and general legend content are outlined in separate sections below.

5.4 MAPPING SCALES

5.4.1 DISCUSSION

1. It was the understanding of the group at the start of the meeting that the 1:1 000 000 scale was given, having been stated by the Western Canada LRTAP Technical Committee. This scale was apparently selected due to the 1:1 000 000 scale used in Eastern Canada Mapping.

2. It was noted that aquatic sensitivity mapping in Western Canada had been done at the 1:2 000 000 scale. Comparisons would require a scale reduction step if soils and geology sensitivity maps were to be compared directly.

3. Concern was expressed for the accuracy of information implied by use of the 1:1 000 000 scale. This concern was particularly for the limited data in northern areas of the western provinces and certainly in the territories. It was felt a smaller scale would be more satisfactory for these areas. Daryl Cowell even suggested several scales; a larger for southern areas and smaller for northern areas. This had been done for some of the mapping in Eastern Canada.

4. It was felt that because interpretive maps (e.g. sensitivity to acid precipitation) have only three or four class and perhaps subclasses, complexity of the maps at a smaller scale than 1:1 000 000 should not be a problem.

5. It was felt that a small scale map for the Yukon and Northwest Territories would be adequate given the data sources available and the lack of current or expected future significant acidic deposition in those areas.

6. Daryl Cowell reminded the group that there is no consistent, up-to-date 1:1 000 000 map base available across Canada. He noted that this may present problems for matching across borders, between provinces, and north to south between territories and provinces. Producing a consistent up-to-date base would be very expensive. He recommended using the smallest scale we could get away with.

7. Other considerations in using 1:1 000 000 scale presentation maps include:

   a) The sheer number of sheets required for full coverage of the Western provinces and the territories (estimated at 20 to 30 all at 1:1 000 000).
   b) The physical limitation of printing facilities and certainly the expense of printing the very large sheets required at the 1:1 000 000 scale.
   c) The potential problems arising from attempts to match 1:1 000 000 maps of different projections (e.g. Mercator, Lambert Conic, Polyconic).

8. Av Mann discussed the matter of scale with R. Wilson from the perspective of the LRTAP Technical Committee. Their conclusion was that with good reasons, a smaller scale was acceptable. However, use of different scales for northern and southern areas of the provinces was not desirable.

5.4.2 CONCLUSIONS

1. Given the following general kinds of problems if a 1:1 000 000 map scale were to be used:

   a) accuracy of mapping and availability of data implied
   b) lack of a consistent, up-to-date 1:1 000 000 base map and potential costs of producing one or coping with the problems of matching different available bases
   c) mapping, drafting and handling the large number of sheets required if 1:1 000 000 coverage of all areas was used
   d) expense or limitations of printing the large sheet sizes associated with the 1:1 000 000 scale

   it was agreed that maps for the four provinces should be produced at 1:2,000,000

2. The recommended scale of mapping for the Yukon and Northwest Territories is 1:5 000 000 given the limited data sources and the very limited nature of present and expected future acidic deposition.

5.5 CLASSIFICATION CRITERIA, CLASS LIMITS AND ASSESSMENT PROCEDURES

5.5.1 DISCUSSION

1. Classification criteria must take into account factors for which data is available and which can and will be mapped, factors for which information can be inferred or for which surrogates are available.

2. Classification criteria for soil sensitivity to acid precipitation have been published in the literature. Exchangeable base content, cation exchange capacity, initial soil acidity, and soil depth are properties frequently used as criteria. Commonly soil texture is used in addition to the above or as a surrogate (e.g. for cation exchange capacity). These criteria have as their target process,

either soil acidification or exchangeable base loss. In effect, concern is for pH change and soil buffering.

3. For classifying sensitivity of soils in agricultural areas of Eastern Canada, Wang and Coote (1981) used exchangeable base content of soils to define high, moderate and low sensitivity (i.e. <6 meq/100/g; 6-15 meq/100g; >15 meq/100g), or in the absence of this information, the pH and texture of soils as surrogates to estimate exchangeable bases.

4. For classifying sensitivity of soils in Western Canada, Shewchuk et. al (1981) used cation exchange capacity to define high, moderate and low sensitivity (i.e. <6 meq/100g; 6-15 meq/100g and >15 meq/100g) on the premise that it is a good indicator of soil buffering capacity. Other "sensitivity pertinent properties" were used to define subclasses.

5. Holowaychuk and Lindsay (1982) likewise used cation exchange capacity to define high, moderate and low sensitivity (i.e. <6 meq/100g; 6-15 meq/100g; >15 meq/100g) while also acknowledging the importance of other factors including: pH, permeability, moisture holding capacity, soil moisture regime, drainage class and minerology.

6. Lands Directorate, DoE in an early paper presented criteria for rating aquatic input sensitivity and forest productivity sensitivity (see Tables labelled 5 and 6, attached) (Cowell et. al., 1981). Subequently, criteria were modified for aquatic input sensitivity, now referred to as "Potential of Soils and Bedrock to Bedrock to Reduce Acidity of Atmospheric Deposition" (See Table labelled 1, attached). An evaluation procedure for applying these criteria were also outlined (See Figure labelled 2, attached) (Lucas and Cowell, 1982). These criteria and the procedure were used for preparing the maps for the final MOI document. (See Table labelled 3-6).

TABLE 5: Forest Productivity Sensitivity

TERRESTRIAL FACTORS	SENSITIVITY		
	LOW	MODERATE	HIGH
Soil Chemistry			
1) Exchangeable Bases Surrogate: Combinations of pH in water (or % Base Saturation)	>15 meq/100g	6 to 15 meq/100g	<6 meq/100g
and one of (a) Family Particle Size	clayey, >pH 5.0 loamy, >pH 5.5 all calcareous soils	clayey, pH 4.5 to 5.0 loamy, pH 5.0 to 5.5 sandy, >pH 5.5	clayey, <pH 4.5 loamy, <pH 5.0 sandy, <pH 5.5
or (b) Texture	clay, silty clay, sandy clay (>35% clay)	silty clay loam, clay loam, sandy clay loam, silt loam, loam (10 to 35% clay)	silt, sandy loam, loamy sand, loamy sand, sand (<10% clay)
or (c) Cation Exchange Capacity	>25 meq/100g	10 to 25 meq/100g	<10 meq/100g
ii) $SO_4^{=}$ Adsorption Capacity as determined by:	low organic matter AND high Al_2O_3 and/or $Fe_2O_3 + Fe_3O_4$		high organic matter AND low Al_2O_3 and/or $Fe_2O_3 + Fe_3O_4$
Soil Depth*	>25 cm	>25 cm	<25 cm*
* If soil depth is less than 25 cm, Underlying Material is incorporated			
Underlying Material			
i) Parent Material	carbonate bearing	non-carbonate bearing	non-carbonate bearing
ii) Bedrock Material	limestone, dolomite, and metamorphic equivalents, calcareous clastic rocks, carbonate rocks interbedded with non-carbonate rocks	volcanic rocks, shales, greywackes, sandstones, ultramafic rocks, gabbro, mudstone, meta-equivalents	granite, granite gneiss, orthoquartzite, syenite

TABLE 6: Aquatic Input Sensitivity

TERRESTRIAL FACTORS			SENSITIVITY		
			LOW	MODERATE	HIGH
Soil Chemistry					
	1)	Exchangeable Bases Surrogate:	>15 meq/100g	6 to 15 meq/100g	<6 meq/100g
		Combinations of pH in water (or % Base Saturation)	clayey, >pH 5.0 loamy, >pH 5.5	clayey, pH 4.5 to 5.0 loamy, pH 5.0 to 5.5 sandy, >pH 5.5	clayey, <pH 4.5 loamy, <pH 5.0 sandy, <pH 5.5
and one of	(a)	Family Particle Size	all calcareous soils		
or	(b)	Texture	clay, silty clay, sandy clay (>35% clay)	silty clay loam, clay loam, sandy clay loam, silt loam, loam (10 to 35% clay)	silt, sandy loam, loamy sand, loamy sand, sand (<10% clay)
or	(c)	Cation Exchange Capacity	>25 meq/100g	10 to 25 meq/100g	<10 meq/100g
	11)	$SO_4^{=}$ Adsorption Capacity as determined by:	low organic matter AND high Al_2O_3 and/or Fe_2O_3 + Fe_3O_4		high organic matter AND low Al_2O_3 and/or Fe_2O_3 + Fe_3O_4
Soil Depth			>1 m	25 - 100 cm	<25 cm
Bedrock Geology			refer to Table 5	---"-	----
Soil Drainage			poor	imperfect to well	rapid
Landform Relief			level	rolling	steep
Vegetation			deciduous	mixed	coniferous
Vegetation Cover			continuous >60%	discontinuous to sparse 20 - 60 %	sparse to barren <20%

TABLE 1. Terrestrial factors and associated criteria for determining the potential of terrestrial ecosystems to reduce the acidity of atmospheric deposition (modified after Cowell et. al. 1981).

TERRESTRIAL FACTORS	POTENTIAL TO REDUCE ACIDITY OF ATMOSPHERIC DEPOSITION		
	HIGH	MODERATE	LOW
Soil Chemistry			
i) Exchangeable Bases Surrogates:	>15 meq/100g	6 to 15 meq/100g	<6 meq/100g
(a) Family Particle Size and pH in water	clayey, >pH 5.0 loamy, >pH 5.5 all calcareous soils	clayey, pH 4.5 to 5.0 loamy, pH 5.0 to 5.5 sandy, >pH 5.5	clayey, <pH 4.5 loamy, <pH 5.0 sandy, <pH 5.5
(b) Texture	clay, silty clay, sandy clay (>35% clay)	silty clay loam, clay loam, sandy clay loam, silt loam, loam (10 to 35% clay)	silt, sandy loam, loamy sand, sand (<10% clay)
(c) Cation Exchange Capacity	>25 meq/100g	10 to 25 meq/100g	<10 meq/100g
ii) SO_4^{2-} Adsorption Capacity	high sulphate adsorption: low organic matter AND high Al_2O_3 and/or Fe_2O_3 + Fe_3O_4 content	———	low sulphate adsorption: high organic matter AND/OR low Al_2O_3 and/or Fe_2O_3 + Fe_3O_4 content
Soil Depth	>1 m	25 cm - 100 cm	<25 cm
Soil Drainage	poor	imperfect to well	rapid
Landform Relief	level	rolling	steep
Vegetation	deciduous	mixed	coniferous
Vegetation Cover	continuous (>60%)	discontinuous to sparse (20 to 60%)	sparse to barren (<20%)
Underlying Material			
i) Parent Material	carbonate bearing	non-carbonate bearing	non-carbonate bearing
ii) Bedrock Material	limestone, dolomite, and metamorphic equivalents, calcareous clastic rocks, carbonate rocks interbedded with non-carbonate rocks	volcanic rocks, shales, greywackes, sandstones, ultramafic rocks, gabbro, mudstone, metaequivalents	granite, granite gneiss, orthoquartzite, syenite

Figure 2: EVALUATION PROCEDURE FOR THE ASSESSMENT OF SOIL AND BEDROCK POTENTIAL TO REDUCE ACIDITY OF ATMOSPHERIC DEPOSITION

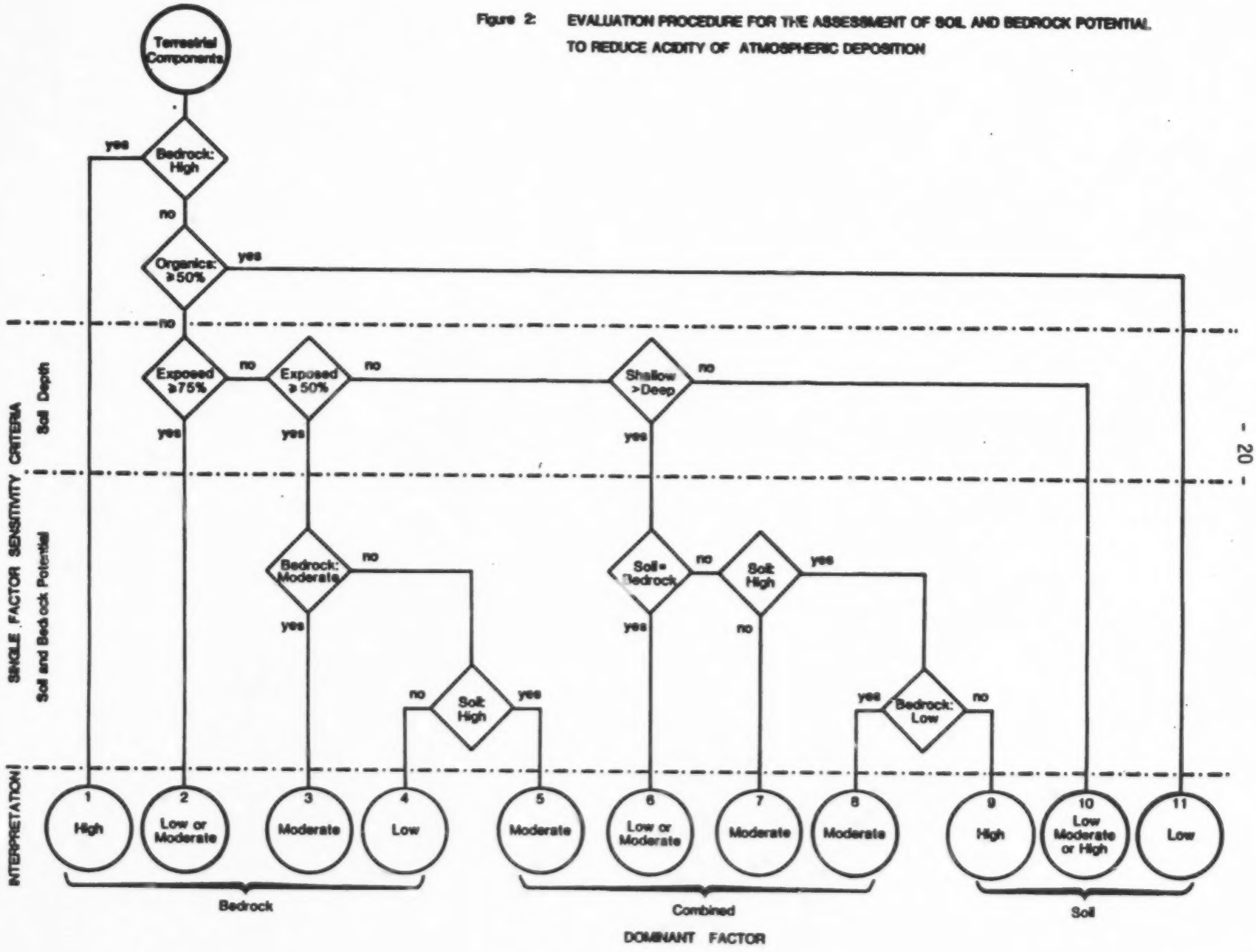

TABLE 4-13. THEORETICAL SENSITIVITIES OF TERRESTRIAL ECOSYSTEMS TO ACIDIC DEPOSITION EFFECTS GIVEN SOIL BASE CONTENT (eq/ha) AND SOIL SULPHATE ADSORPTION CAPACITY (eq/ha) (modified from Johnson and Olson in press)

	SOIL PROPERTIES		TERRESTRIAL SENSITIVITY TO:		
	pH	CEC	Base Cation Loss	Soil Acidification	Al Solubilization
			I. Nonsulphate-adsorbing Soils		
1.	>6	High	High	Low	Low
2.	>6	Low	High	Low-moderate	Low-moderate
3.	5-6	High	High	Moderate	Moderate
4.	5-6	Low	High	High	Moderate
5.	<5	High	Moderate	Low	Moderate
6.	<5	Low	Moderate	Low	High
			II. Sulphate-adsorbing Soils		
7.	>6	High		Rare or nonexistent cases	
8.	>6	Low			
9.	5-6	High	Low	Moderate	Moderate
10.	5-6	Low	Low	High	Moderate-high
11.	<5	High	Low	Moderate	Moderate-high
12.	<5	Low	Low	High	High

POTENTIAL SENSITIVITIES TO BASE CATION LOSS, SOIL ACIDIFICATION AND ALUMINUM SOLUBILIZATION BY PREDICTED SOIL PROPERTIES AS DEFINED BY MAP UNITS FOR EASTERN CANADA.

MAP UNIT	BEDROCK* TYPE	SOIL CATEGORY	PREDICTED SOIL PROPERTIES		SENSITIVITY TO:		
			pH	CEC	BASE CATION LOSS	SOIL ACIDIFICATION	ALUMINUM SOLUBILIZATION
A	1,2,3 or 4	Organic	< 5	High	Low-Moderate(?)	Low(?)	Low-Moderate(?)
B	1				High	Low-Moderate	Low-Moderate
	2,3				High	High	Moderate
	4				Moderate	Low	High
C_1	1,2 or 3	Sand	> 5	Low	High	Low-Moderate	Low-Moderate
C_2	4	Sand	< 5	High	Moderate	Low	Moderate-High
			< 5	Low	Moderate	Low	High
C_1^*	4	Sand	< 5	High	Low	Moderate	Moderate-High
			< 5	Low	Low	High	High
D_1	1,2 or 3	Loam	> 6	Low	High	Low-Moderate	Low-Moderate
			> 6	High	High	Low	Low
D_2	4	Loam	< 5	High	Moderate	Low	Moderate-High
			< 5	Low	Moderate	Low	High
			5-6	High	High	Moderate	Moderate
			5-6	Low	High	High	Moderate
D_1^*	4	Loam	< 5	High	Low	Moderate	Moderate-High
			< 5	Low	Low	High	High
E_1	1,2 or 3	Clay	> 6	High	High	Low	Low
E_2	4	Clay	> 6	High	High	Low	Low

*Bedrock sensitivity classes were defined by Shilts et al. (1981) on the basis of lithology.

Type 1 - Limestone, marble, dolomite.

Type 2 - Carbonate-rich siliceous sedimentary: shale, limestone; noncalcareous siliceous with carbonate interbeds: shale, siltstone, dolomite; quartzose sandstone with carbonates.

Type 3 - Ultramafic rocks, serpentine, noncalcareous siliceous sedimentary rocks: black shale, slate, chert; gabbro, anorthosite: gabbro, diorite; basaltic and associated sedimentary: mafic volcanic rocks.

Type 4 - Granite, gneiss, quartzose sandstone, syenitic and associated alkalic rocks.

**Sulphate-adsorbing soils.

Canada

7. Efforts by Lands Directorate for the final MOI document relative to terrestrial sensitivity interpretations were directed not at forest or agricultural productivity, or even an integrated rating of soils and geology sensitivity, but at specific terrestrial ecosystem effects, namely: loss of base cations, soil acidication, and Al solubilization. (Table labelled 4-13, attached, represents guidelines for rating sensitivity of soils to these target processes. A copy of an example table is attached which shows ratings of mapping units in Eastern Canada according to sensitivity to these target processes).

8. Criteria for rating agricultural and forest productivity sensitivity are stated (MOI final document) to be dependent on future understanding of cause-effect linkages between acidic deposition and impacts on vegetation. (The relative importance of the processes, base cation loss, soil acidification, Al solubilization etc., to forest and agricultural productivity are not known).

9. Despite the reluctance to define criteria and prepare a map of sensitivity of forest and agricultural productivity in the MOI process, the Western Canada Soils and Geology Committee felt the need to define such criteria and produce a map. The criteria would require certain assumptions about significance of soil processes (e.g. base loss, acidification, Al solubilization) and the sensitivity of mapping units to these processes could be listed along with the rating of sensitivity of forest and agricultural productivity.

10. The attempts at a combination of sensitivity ratings for two or more of these processes in previous "soil sensitivity rating" criteria (e.g.Wang and Coote, 1981; Holowaychuk and Lindsay, 1982) was recognized and considered for adoption. However, the merits of individual ratings followed by a rating of sensitivity of forest and agricultural productivity were considered significant.

5.5.2 CONCLUSIONS

1. The terrestrial factors and sensitivity class limits (i.e. the criteria), and the evaluation procedure for assessing soil and bedrock potential to reduce acidity of atmospheric deposition used by the Lands Directorate, DoE, in Eastern Canada were accepted for application in Western Canada with the following points of emphasis or items of modification:

   a) these criteria and the assessment procedure are for aquatic input sensitivity, an interpretation not originally planned for soil and geology sensitivity interpretation.
   b) these criteria attempt to integrate or combine soils and geology information in a systematic way to arrive at a single sensitivity rating.
   c) adoption of these criteria require the definition for each map unit (by direct information from source maps or by inference) of soil chemistry (exchangeable bases or surrogates), soil depth, bedrock exposure and bedrock type.
   d) the criteria for separating shallow and deep soils according to the proposed scheme is 1 m.
   e) the boundary values to be used for bedrock exposure within polygon should be 70% and 30% rather than 75% and 50%. These are chosen due to commonly used proportions for complex mapping units.

2. A procedure of separately rating sensitivity of soils to the three processes, base cation loss, soil acidification and Al solubilization was agreed to. The guidelines table for this process (Table labelled as 4-13) as presented in the final MoI documents was accepted as guidance.

3. The need for producing a map of Forest and Agricultural Productivity Sensitivity was considered a priority. This would require certain assumptions for combining sensitivities to the

soil processes indicated. Some assumptions discussed and tentatively accepted for rating Forest and Agricultural Productivity Sensitivity were as follows:

a) soil sensitivity to Al solubilization is a significant determinant in rating forest and agricultural productivity. Mounting evidence points to high soluble Al as a cause for reduced productivity. (Already acid, mineral soils, particularly those with low CEC would thus have a high sensitivity rating).
b) soil sensitivity to base cation loss is a significant determinant in rating forest and agricultural productivity but must be considered in combination with CEC and initial pH. (A soil highly sensitive to base cation loss would only result in a high sensitivity rating for forest and agricultural productivity if the amount of bases were initially low i.e. low CEC and/or low initial pH and therefore low base saturation).

5.6 MAPPING METHODS

5.6.1 DISCUSSION

1. Methods to be used in mapping follow in part from the definition of sensitivity agreed to, from the target ecosystems and processes which are agreed should be addressed, and from the classification criteria (factors and class limits) accepted.

2. Composition and labelling of polygons (e.g. simple or complex) affects the information retained on the map. However, it must be recognized that in an interpretive sensitivity map (e.g. coloured with three classes) selection of rating of one of the polygon components will have to be made.

3. Map legends should be used to provide more detailed information on properties and ratings of mapping units. Several different sensitivity ratings for each mapping unit can therefore be noted.

4. A likely approach to producing the basic soils and geology map would be to use the basic polygons on a generalized soils map, soil landscapes map, or surficial materials map and overlaying a bedrock map so as to attach to each polygon, information on bedrock type. (This was in fact the approach used in the MOI process as well. Ecodistrict maps or Ontario Land Inventory maps were overlayed with Shilts (1981) bedrock maps and the bedrock types were described for polygons from the former).

5.6.2 CONCLUSIONS

1. Mapped polygons on the basic map to be prepared should be labelled to indicate status of the factors agreed upon as stated in the conclusions on criteria (i.e. soil chemistry or surrogates, soil depth, bedrock exposure, and organic terrain proportions, and bedrock type).

2. Complex polygons (i.e. with more than one combination of factors to be mapped) are to be expected at the scale of mapping to be carried out. The following guidelines should apply in describing and labelling polygons:

   a) No more than two components should be identified in the label.
   b) Any component occupying less than 20 percent of the area of a polygon should not be noted on the map.

3. The map legend on the basic map to be prepared should contain tabular information for each mapping unit indicating information on status of each of the rating factors (as noted in discussion and conclusions on criteria):

a) Soil Chemistry/Surrogate - Exchangeable base class
- texture class
- CEC class
- pH class

b) Soil Depth class

c) Bedrock type

as well as sensitivity/potential ratings for the following:

a) Potential of Soils and Geology to Reduce Acidity of Incoming Atmospheric Deposition

b) Sensitivity of soils to base cation loss

c) Sensitivity of soils to acidification

d) Sensitivity of soils to aluminum solubilization

e) Forest and Agricultural Productivity

4. Maps depicting the three sensitivity/potential classes for a and e above are recommended. These might be in red, yellow and green (for high, moderate and low sensitivity); in grey-tone etc. Polygon boundaries and symbols should be retained as background on these sensitivity maps.

5.7 ORGANIC SOILS

5.7.1 DISCUSSION

1. Organic soils present a special situation, can be problematic, and have been raised for special consideration in relation to sensitivity rating. (They were identified in a previous report (Wiens, 1982) as requiring special attention.

2. Consideration has been given in Section 5.5 to the occurrence of organic soils on the landscape and their influence on rating the "Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition."

3. Attention must be given to rating of organic soils for sensitivity to the processes: base cation loss, soil acidification, and Al solubilization and subsequently on rating Forest and Agricultural Productivity Sensitivity.

4. Modification of soil chemistry factors to account for the low bulk density of organic soils is most important where basic information is available. It was recognized that the high apparent buffering capacity, CEC etc. of organic soils expressed on a weight basis, becomes comparable to mineral soils when expressed on a volume basis.

5.7.2 CONCLUSIONS

1. For rating the "Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition" the procedure as use in the MOI process and discussed in section 5.5 should be used.

2. When rating organic soils for sensitivity to the soil processes: base cation loss, soil acidification, and Al solubilization, basic chemistry data should be modified to express it on a volume corrected basis so it can be compared with mineral soil data. (An appropriate bulk density value may have to be assumed).

3. In areas of organic soils where basic data is not available a legend class such as "undifferentiated organic soils" may have to be used.

5.8 BARREN AREAS

5.8.1 DISCUSSION

1. Barren areas include areas referred to in section 5.5 as having $\geq$ 75% bedrock exposure.

2. Barren areas would also include areas occupied by glaciers.

5.8.2 CONCLUSIONS

1. Areas of $\geq$ 75% bedrock exposure would be so indicated on the basic soils and geology map. A rating according to the assessment procedure for "Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition" would be based on bedrock type.

2. Barren areas would not be rated for sensitivity to the processes: base cation loss, soil acidification, Al solubilization or for Forest and Agricultural Productivity Sensitivity. They would be suitably designated on the legend of the latter interpretive map.

5.9 ACID LOADING LIMITS

5.9.1 DISCUSSION

1. Generally agreed that Soils and Geology Sensitivity Mapping Committee need not deal with precipitation loading.

2. Another group reporting to the Technical Committee (actually AES) will provide loading estimates for Western Canada. This map can then be overlayed on the (soils and geology sensitivity maps).

3. Wang and Coote (1981) have assumed a loading rate of 60 kg/ha/year along with a limit of 25 percent base loss over 25 years in arriving at the <6,6-15 and >15 meq/100g exchangeable base limits for high, moderate and low soil sensitivity classes respectively.

4. According to Daryl Cowell, the 60 kg/ha/year limit is reasonable.

5.9.2 CONCLUSIONS

1. It was agreed that the soil sensitivity classes as defined by Wang and Coote (1981) and the underlying loading rates were acceptable and no better alternative suggestions could be made.

2. No further considerations would be given at this time to loading limits. (These may be expected to come under review in each province).

6. CONCLUDING COMMENTS

6.1 TIMING

1. The Western Canada LRTAP Technical Committee has indicated the following target dates in the minutes of their 15-16 March 1983, meeting:

   a) January, 1984 - First map for Western Canada
      (This will include an interim report which will be a 3-page synthesis of provincial reports which may have some border inconsistencies)
   b) March, 1985 - Final map
      (This will include results of further surveys)

2. The flexibility of the first date will need to be checked with the Technical Committee given some of the conclusions on classification criteria, mapping methods and interpretive maps to be prepared. (N.B. The recommendations of the Soils and Geology Committee is to produce two interpretive maps on the basic soils and geology map to be prepared).

3. The statement regarding inclusion of results of further surveys for the March, 1985 target date will need clarification.

4. A statement of progress will be required for the meeting of the Technical Committe on October 26, 1983.

6.2 ALTERATIONS TO CONCLUSIONS IN THIS REPORT

1. It is likely that some of the discussion and resultant conclusions have been inadequately or incorrectly stated.

2. It is also likely that provincial/territory representatives in discussion with their colleagues or as a result of experience will have suggestions for modification/refinement in the recommendations as stated in the various conclusions.

3. It is requested that the suggestions for correction, modification, refinement be forwarded to J.H. Wiens with copies to the other committee members as soon as possible. (Names and addresses are attached as an Appendix to this report).

6.3 REVIEW OF DRAFT MAP LEGENDS, MAPS, REPORTS

1. Communication between provinces/territories and the federal agencies will be required if the objective of compatibility is to be achieved.

2. Participants are encouraged to freely circulate draft legends, maps, reports etc. (again, names and addresses are in the Appendix).

3. J.H. Wiens as chairman, will attempt to facilitate interchange and seek resolutions of issues as needed pending changes to organization which may be directed by the Technical Committee.

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APPENDIX

Names and Addresses of Soils
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